Analysis of MRR and SR with Different Electrode for SS 316 on Die-Sinking EDM using Taguchi Technique

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Received: 13 December 2012 Accepted: 2 January 2013 Published: 15 January 2013

Abstract

The development of new materials show the immense growth but the major problem, it is very difficult tomachine the newly developed materials. So it is necessary to adopt some new machining methods. Electrical Discharge Machining (EDM) is a non-traditional and most popular machining method to manufacture dies, punches and press tools because of its capability to produce complicated, intricate shapes and to machine hard materials. From the industrial point of view stainless steel 316 is a very commonly used material due to its property of resistant to corrosion. During experimentation, electrode material, current and pulseon time were taken as variables for the study of material removal rate and surface roughness. Three different electrode materials copper, brass and graphite were used with EDM oil as a dielectric fluid in the experiment. Using Taguchi method, L9 orthogonal array has been chosen and three levels corresponding to each of the variables are taken. Experiments have been performed as per the set of experiments designed in the orthogonal array. Results of experimentation were analyzed analytically as well as graphically. Signal to Noise ratio was calculated to analyze the effect of input parameter more accurately. It is found that ANOVA has unable to find the key significant parameters for the output response due to less number of variables and factors. The optimal value of MRR and SR were also calculated using their signal to noise ratio value.

Index terms— EDM, taguchi design orthogonal array

1 Analysis of MRR and SR with Different Electrode

for SS 316 on Die-Sinking EDM using Taguchi Technique Suraj Choudhary ? , Krishan Kant ? & Parveen Saini ?

Abstract -The development of new materials show the immense growth but the major problem, it is very difficult to machine the newly developed materials. So it is necessary to adopt some new machining methods. Electrical Discharge Machining (EDM) is a non-traditional and most popular machining method to manufacture dies, punches and press tools because of its capability to produce complicated, intricate shapes and to machine hard materials. From the industrial point of view stainless steel 316 is a very commonly used material due to its property of resistant to corrosion. During experimentation, electrode material, current and pulseon time were taken as variables for the study of material removal rate and surface roughness. Three different electrode materials copper, brass and graphite were used with EDM oil as a dielectric fluid in the experiment. Using Taguchi method, L 9 orthogonal array has been chosen and three levels corresponding to each of the variables are taken. Experiments have been performed as per the set of experiments designed in the orthogonal array. Results of experimentation were analyzed analytically as well as graphically. Signal to Noise ratio was calculated to analyze the effect of input parameter more accurately. It is found that ANOVA has unable to find the key significant parameters for the output response due to less number of variables and factors. The optimal value

of MRR and SR were also calculated using their signal to noise ratio value. From the experimental results it is clear that copper electrode, higher current value (30A) and pulse-on value (50µs) possess highest MRR while brass electrode, lower current value (18A) and higher pulse-on time (65µs) value has better surface finish.

Keywords : EDM, taguchi design orthogonal array.

2 a) Electrical Discharge Machining (EDM)

Electrical Discharge Machining is a nontraditional concept of machining. It has been widely used for making dies, punches and molds. It is also used in manufacturing of finished parts for automotive and aerospace industries and surgical components. It is also called spark erosion machining method because in this method material ofwork piece is removed by erosion effect by the electricspark. This process can be successfully employed to machine electrically conductive parts irrespective of their hardness, shape and toughness [1]. The EDM machine has a tool and a work piece which is to be machined. In die-sinking EDM, the shape of tool used for spark generation is a replica of the shape of which is to be produced. The tool electrode and the work are held at an accurately controlled distance from one another, which are dependent on the operating conditions and referred to as spark gap. Both the tool and the work piece are dipped in a dielectric medium like kerosene, EDM oil etc [2].

3 b) Historical Background

The origin of electrical discharge machining goes far back to 1770, when English scientist Joseph Priestly discovered the erosive effect of electrical discharges on metals but after that the full advantage of this concept had not been taken till 1943. The Lazarenko, used resistance capacitance type of power supply, which is widely used in 1950s. This idea gave a new born to the EDM process but during the 1948-1950 this idea started to spread in the industrial world area. In 1980s the advancement of Computer Numerical Control (CNC) in EDM has brought a great turn in improving the efficiency of machining operations, pulse recognition, real time analysis, A.C tool wear analysis, controls and expert systems [3,1]. Wire EDM machine (WEDM) touched the new heights of performance. The phase 1990-95 brought the new parametric approach, Neutral networks and Fuzzy controllers. Modern era from 1995 till date brought in various new aspects in EDM machining such as micromachining by EDM and machining without liquid dielectric. Now EDM is more accepted technique for material removal next to CNC Milling [4].

4 c) Process of EDM

The working principle of EDM is based on the thermoelectric energy. This energy is created between the electrode and the work piece, dipped in dielectric fluid with the passage of electric current. The work piece and electrode are separated by a small gap called spark gap. Pulsed arc discharges occur in this gap filled with a dielectric liquid like hydrocarbon oil or de-ionized (demineralized) water. The technique of material removal with EDM is still arguable. This is because ignition of electrical discharges in a liquid filled gap, when applying EDM, is mostly interpreted as ion action identical as found by physical research of discharges in air or in vacuum.

As well as with investigations on the break through strength of insulating hydrocarbon liquids. EDM with a system comprising two major components: a machine tool and power supply [5]. The electrode (tool) is held in machine tool, which advances towards the work piece and produces a high frequency series of electrical spark discharge.

The spark is generated by a pulse generator between electrode and work material. The reduced spark gap results that the applied voltage is high enough to ionize the dielectric fluid. The electrode and work piece are separated by the short duration pulses which are generated in liquid dielectric gap. The spark is generated at the smallest inter electrode gap. The erosive effect of discharges removes the material from the tool and the work piece. The discharge energy is concentrated on very small cross-section with the dielectric fluid. It flushes out the removed material during machining and cools the electrode from heating. The erosion of work piece material uses electrical energy and converts them into the thermal energy through a series of electrical discharges.

The material is removed by partial vaporization or melting. The removed debris which is in molten state re-soldified and flushes out with help of dielectric fluid. The thermal energy generates plasma between tool and work material having temperature range 8000?C to 12000?C and high as 20000?C. When the DC supply is switch off then plasma channel breaks down results in reduction in temperatures [6].

In EDM operation, the material removal rate is less than the conventional machining. The amount of material removal is dependent upon the amount of pulsed current in each discharge, frequency of the discharge, dielectric flushing condition, electrode material and work piece material. Surface finish is an important factor for the work-piece. It becomes more vital so as to produce a better surface when hard materials are machined, requiring no subsequent polishing.

Surface finish is also important in the case of tools and dies for moulding as well as drawing operations. Surface finish mainly depends upon the type of electrode used, value of discharged current and polarity [4].

Many researchers used the steel for their experimentation like AISI 304, En 31, XW 42 and many more on EDM but still no work is done on Stainless Steel 316 which is one of the most commonly used steel in manufacturing industries due to of its better corrosion resistance, weldability properties and called as "marine grade stainless steel". Mostly work has been done by using kerosene as a dielectric only few researchers used the EDM oil. In all steel that used as studied in literature brass and graphite is the least used as a tool electrode. Only few researchers used the ANOVA technique for the analysis of result due to lack of experimental design. Without the use of ANOVA, no significant parameters and individual contribution of input parameter to the response cannot be calculated [7].

The behaviour of different material is different during the machining both for electrode and work piece in EDM because every material have different composition so it is necessary to know that which material gives the highest material removal rate and better surface finish with suitable electrode especially for those material which is commonly in use. So in this work it was proposed to study the effects of different input parameter electrode material, current and pulse-on time on Material removal rate (MRR) and Surface roughness (SR) with EDM oil as a dielectric. The experimental design has been done by using Taguchi technique. The response has been analysed using S/N ratio and analysis of Variance. L 9 orthogonal array was used in this experiment for the machining parameters. This orthogonal array consists of three control factors and three levels as shown in the table no 4.1. In this study, the material removal rate and surface roughness were analyzed on the basis of maximum and minimum values respectively. So by taguchi method "higher is better" chooses for MRR, and "smaller is better" for SR. Both of the output response was performed with three replication at each set value. The results were analysed on S/N ratio and analysis of variance (ANOVA) which is based on Taguchi method. [7] Higher is better (S/N) HB = -10 log (MSD HB)

Where MSD HB = MSD HB = Mean Square deviation for lower the better response Table **??**.

5 1: Factors & their levels for experiments

The knowledge of the contribution of individual factors is critically important for the control the final response. The analysis of variance (ANOVA) is a common statistical technique to determine the percent contribution of each factor for results of the experiment. It calculates parameters known as sum of squares SS(tr), degree of freedom (DOF), variance and percentage of each factor. Since the procedure of ANOVA is a very complicated and employs a considerable of statistical formula, only a brief description of is given as following. The Sum of Squares SS(tr) is a measure of the deviation of the experimental data from the mean value of the data [8].

6 SS(tr) = n y i ? y 2 c i=1

Where n = number of response observations y = mean of all observationsy i = mean of i th response

The sum of square of error (SSE) within the groups is calculated by the formulaSSE = y ij ? y i 2 n j=1 c i=1

Where c = no of trials y ij = Corresponding element of i, j The mean sum of square (? ? 2) between the treatments isS B 2 = n y i ?y 2 c i=1 c?1

The degree of freedom for the factor between treatments is c-1 and for the error is n T -c. The Fisher's ratio is also called F value. The principle of the F test is that the larger value for a particular parameter, the greater the effect on the performance characteristics due to the change in that parameter. F value is defined as:F =

Mean square for the term Mean square for the error term The purpose of analysis of variance is to determine which input parameter significantly affects the MRR and SR. shown in table no. 5.4 and 5.7 for MRR and SR respectively. In this case the ANOVA table is not supporting because all the parameters were found insignificant. The calculated F value is less than the F critical which is 99. The no. of variables were less for analysing it with ANOVA. For selecting the proper significant parameter with help of ANOVA, larger orthogonal array should be selected. [9] a) Optimal Design for MRR and SR In the experimental analysis, main effect plot of S/N ratio for MRR and SR is used for estimating the S/N ratio of MRR with optimal design condition. As shown in the figure no.5.1, electrode material (A) has highest value at level 1 so named it A1. For the current (B) and pulse-on (C) it is B3 and C2 respectively. After evaluating the optimal parameter settings, the next step of the Taguchi approach is to predict and verify the enhancement of quality characteristics using the optimal parametric combination [7]. The estimated S/N ratio using the optimal level of the design parameters can be calculated:n opt = n m + n i ? n m a i

Where n m = the total mean of S/N ratio n i = mean S/N ratio at optimum level a = number of design parameters that effect quality characteristics Based on the above equation the estimated multi response signal to noise ratio can be obtained. As per the optimal level again the experiment is performed as A1 B3 C2. The experimental value that is obtained is 4.10. So the value of percentage change is 11.82%.

For the surface roughness as shown in figure no.5.4 electrode material (A) has highest value at level 2 means at brass so we named it A2. For the current (B) and pulse-on (C) it is B1 and C3 respectively. The estimated S/N ratio using the optimal level of the design parameters can be calculated: As per the optimal level again the experiment is performed as A2 B1 C3. The experimental value that is obtained is 4.41. So the value of percentage change is 1.78%.

In the present study, for EDM process the effect of electrode material (copper, brass and graphite), current and pulse-on has been investigated. The effect of input parameter on output response Material removal rate and Surface roughness were analysed for work material stainless steel 316. L9 orthogonal array based on Taguchi design and ANOVA was performed for analysing the result. 1. For the MRR, electrode material is most influencing factor and then discharge current and the last is pulse-on time. MRR increases with the higher value of discharge current. 2. Copper electrode shows the highest MRR while the brass electrode shows the least MRR. For lower value of pulse-on time (35µs) the MRR is low and highest at 50µs. At current 30A, the MRR is highest 3. For surface roughness, the electrode material is most influencing factor and then discharge current and the last is pulse-on time. SR is better with lower value of current. 4. Brass electrode shows the better surface finish while the copper electrode shows the worst surface finish as comparative to graphite and brass. For higher value of pulse-on (65µs) time the SR is best. At higher current 30A, the SR is highest which is not preferable.

7 Graphite electrode has intermediate value of MRR

and SR as comparative to copper and brass electrode. For further study more input parameter can be considered.

Figure 1:

[1]

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Figure 2: Figure 3 . 1 :

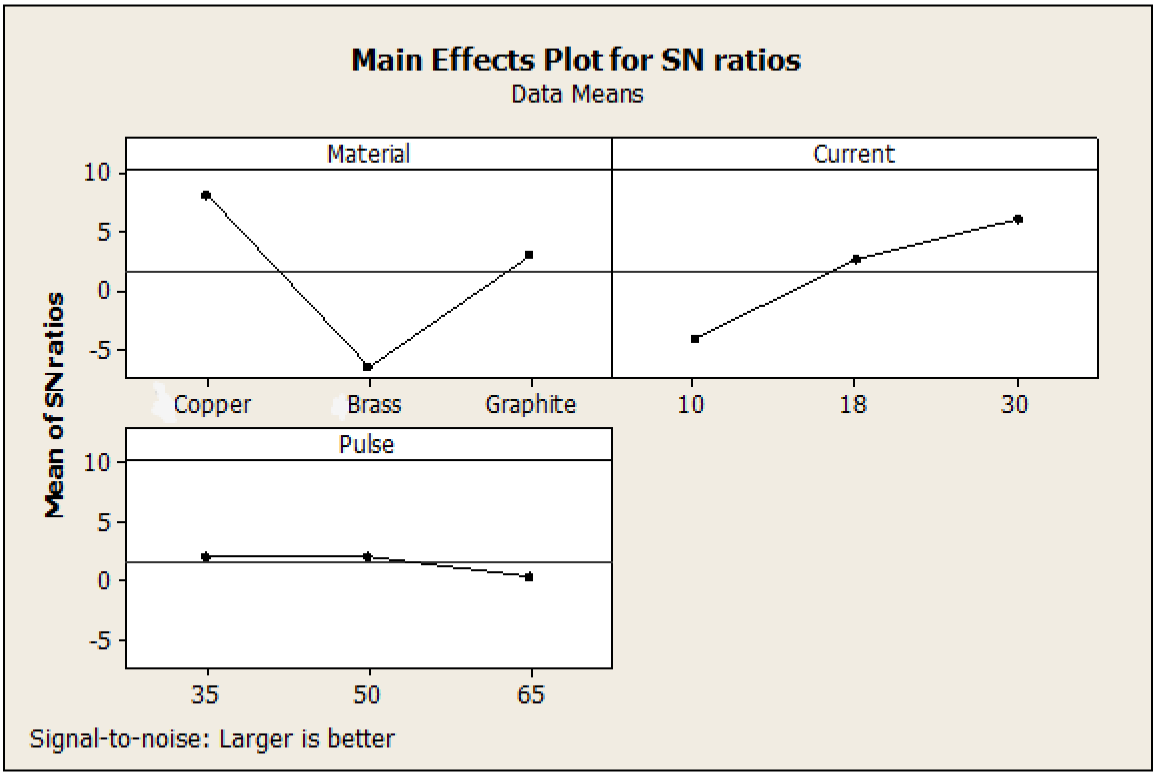


Figure 3:)

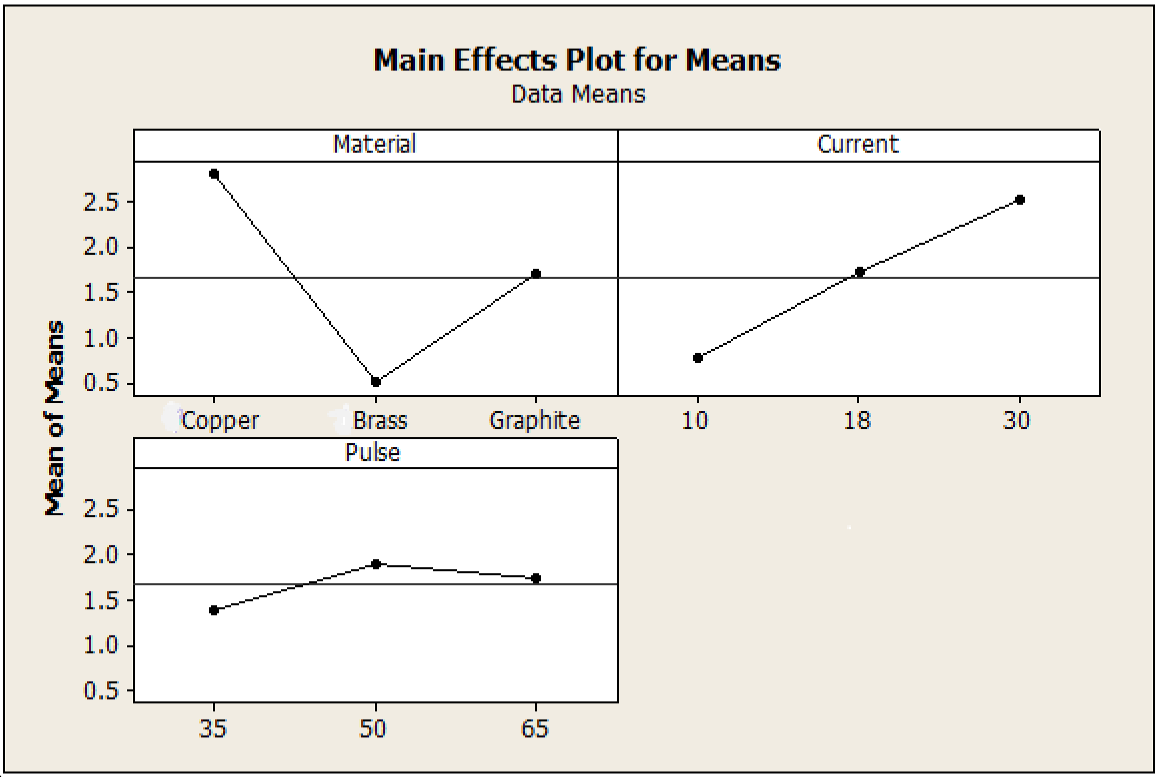
51 

Figure 4: Figure No. 5 . 1 :

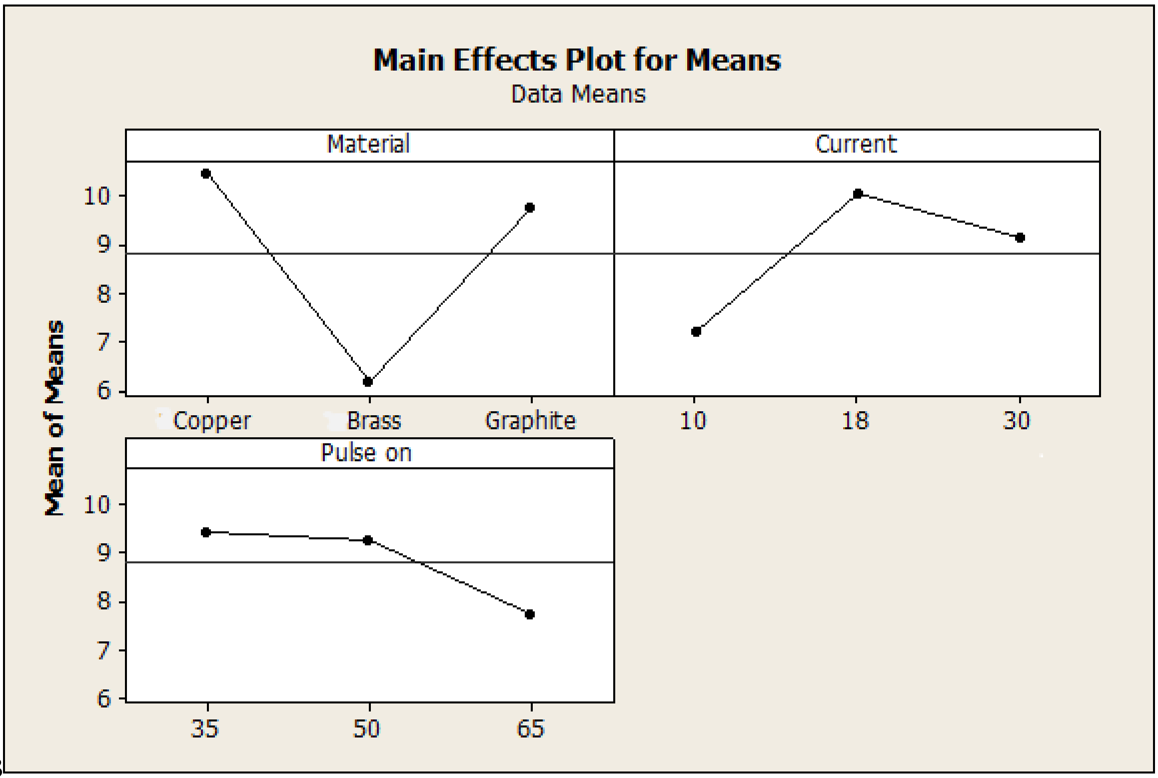
53 

Figure 5: Figure No. 5 . 3 :

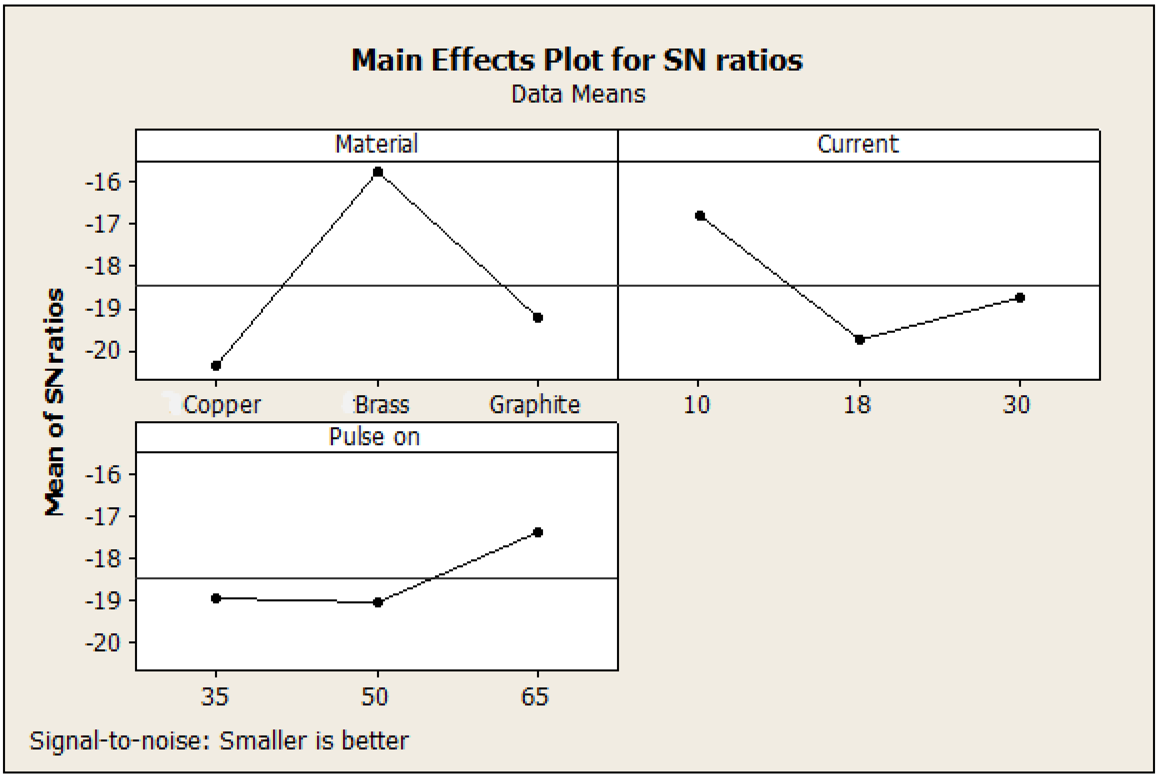


Figure 6:

3

Figure 7: Table 3 .

3

2 : Composition of stainless steel 316

C(%)	Mn	Si	P	S	Cr	Mo	Ni	
0.08	2	0.75	0.045	0.03	18	3	14	0.10

The composition for the stainless steel 316 shown inTable No.3.2. The work piece dimensions for the experiment were ?60 mm and thickness 10 mm. The mechanical, physical and electrical properties of stainless steel 316 are shown in the table no. 3.3 and 3.4 respectively.

Figure 8: Table 3 .

3

Tensile stress (MPa)	Yield stress (MPa)	Rockwell hardness (HRB)		Brinell hardness (HB)
515	205	95		217

Table 3.4 : Physical and electrical properties for Stainless steel 316

Density (Kg/m3)	Elastic Modulus (GPa)	Thermal Conductivity (W/m.K) at 100?C	Specific heat 0-100?C (J/Kg.K)	Electrical Restivity (n?.m)
8000	193	16.3	500	740

This grade cannot heat treated by thermal treatment. Stainless steel 316 typical applications include: Laboratory equipments, Food preparation

Figure 9: Table 3 .

5

Experiment No.	Electrode Material	Current (Amp)	Pulse on (µs)	Material Removal Rate (gms) 1 2 3			S/N ratio for MRR	Surface Roughness		
1	Copper	10	35	1.44	1.42	1.55	3.3273	9.96	9.99	10.13
2	Copper	18	50	2.82	2.78	2.77	8.9109	10.38	10.47	10.53
3	Copper	30	65	4.14	4.22	4.15	12.4008	11.02	10.86	10.82
4	Brass	10	50	0.28	0.29	0.3	-10.7624	6.20	6.26	6.23
5	Brass	18	65	0.48	0.46	0.5	-6.3909	6.86	6.88	6.92
6	Brass	30	35	0.71	0.75	0.79	-2.5235	5.45	5.39	5.41
7	Graphite	10	65	0.58	0.54	0.59	-4.9018	5.36	5.32	5.40
8	Graphite	18	35	1.86	1.88	2.02	5.6487	12.77	12.84	12.76
9	Graphite	30	50	2.66	2.61	2.56	8.3296	11.1	11.21	11.01

for MRR

Level	Electrode material	Current	Pulse-on
1	8.213	-4.1123	2.1508
2	-6.5589	2.7229	2.1594
3	3.0255	6.0689	0.3694
Delta	14.7719	10.1812	1.79
Rank	1	2	3

Table No 5.3 : Average effect response table of raw data for MRR

Level	Electrode material	Current	Pulse-on
1	2.81	0.7767	1.38
2	0.5067	1.73	1.8967
3	1.7	2.51	1.74
Delta	2.3033	1.733	0.5167
Rank	1	2	3

[Note: Table No 5.2 : Average effect response table of S/N ratio]

Figure 10: Table 5 .

No

Source	Sum squares of	Degree of freedom	Mean square	F value
Material	7.9615	2	3.9807	8.27
Current	4.5217	2	2.2608	4.69
Pulse-on	0.4211	2	0.2105	0.44
Error	0.9631	2	0.4815	
Total	13.8674	8		

Figure 11: Table No .

No

	for SR		
Level	Electrode material	Current	Pulse-on
1	-20.39	-16.83	-18.94
2	-15.78	-19.76	-19.06
3	-19.21	-18.78	-17.37
Delta	4.61	2.93	1.70
Rank	1	2	3

[Note: 5.5 : Average effect response table of S/N ratio]

Figure 12: Table No .

No5

	for SR		
Level	Electrode material	Current	Pulse-on
1	10.460	7.203	9.410
2	6.180	10.047	9.267
3	9.753	9.143	7.717
Delta	4.280	2.843	1.693
Rank	1	2	3

[Note: .6 : Average effect response table of raw data]

Figure 13: Table No . 5

No

Source	Sum of squares	Degree of freedom	Mean square	F value
Material	31.586	2	15.793	2.28
Current	12.664	2	6.332	0.91
Pulse	5.290	2	2.645	0.38
Error	13.880	2	6.940	
Total	63.421	8		

Figure 14: Table No .

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